CTIA
Building The Wireless Future™
Cellular Telecommunications & Internet Association

February 8, 2002

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
445 12th Street, S.W.
12th Street Lobby, TW-A325
Washington, DC 20554

Re*:** ***Ex Parte **Presentation**
ET Docket No. 00-258; RM 9920; RM 9911

Dear Mr. Caton:

On February 8, 2002, the Cellular Telecommunications & Internet Association ("CTIA") represented by Diane Cornell, Vice President for Regulatory Policy, along with Steve Sharkey, Director for Spectrum and Standards Strategy, and Dr. Robert Kubik, Manager for Spectrum and Regulatory Policy, of Motorola, met with Lauren Van Wazer, Special Counsel to the Office Chief and Julius Knapp, Deputy Chief, in the Office of Engineering and Technology, and William Lane and Charles Rush, Senior Engineers, in the Wireless Telecommunications Bureau. The parties discussed issues relating to evaluating spectrum for advanced mobile services, focusing on the 1710-1770 MHz band. In particular, the parties discussed the attached presentation.

Pursuant to Section 1.1206 of the Commission's Rules, this letter is being filed with your office. If you have any questions concerning this submission, please contact the undersigned.

Sincerely,

Diane Cornell

Diane Cornell

cc: Lauren Van Wazer
Charles Rush
William Lane
Julius Knapp

Compatibility between DoD Satellite Operations (SATOPS) and 3G terrestrial stations operating in 1710 – 1770 MHz

Summary:

Satellite systems operating in channels 1-3 (1762-1770 MHz) pose a limited risk for interference to 3G base station receivers operating below 1770 MHz. A single system (USAPEX), currently 8 years old, requires further evaluation as to the overlap between deployment of 3G systems (post 2004) and the end-of-life expectation of the USAPEX system. If there is a significant overlap mitigation measures outlined in the report should be considered.

Satellite systems operating in channel 4 appear to have no risk of interfering with 3G base stations. Satellite systems operation in channel 5 will have some reduction in potential interference due base band filtering. Two systems (L-92 and CRRES) are, respectfully, 10 and 12 years old. Evaluation as to the overlap between deployment of 3G systems (post 2004) and the end-of-life expectation of these systems are required. If there is a significant overlap mitigation measures outlined in the report should be considered.

Satellite systems operating in channels 6 and higher appear to have no risk of interference to 3G base station receivers due to the large frequency separation and the application of base band filtering to the SATOPS earth terminals. Indications are that these two factors will reduce emissions into the 3G receivers by 90 dB.

Table of Contents:

1 Satellite Operations in 1761-1842 MHz

ITU maintains a database of almost 5500 geostationary satellites, 700 non-geostationary satellites and 7000 earth stations.[1] A search of this database results in 109 systems registered to the US in the band 1761-1842 MHz. Of those 87 have a Geostationary orbit (GSO) and 22 have a non-Geostationary Orbit (NGSO), show in Figure 1 is the utilization of the various channels.[2]

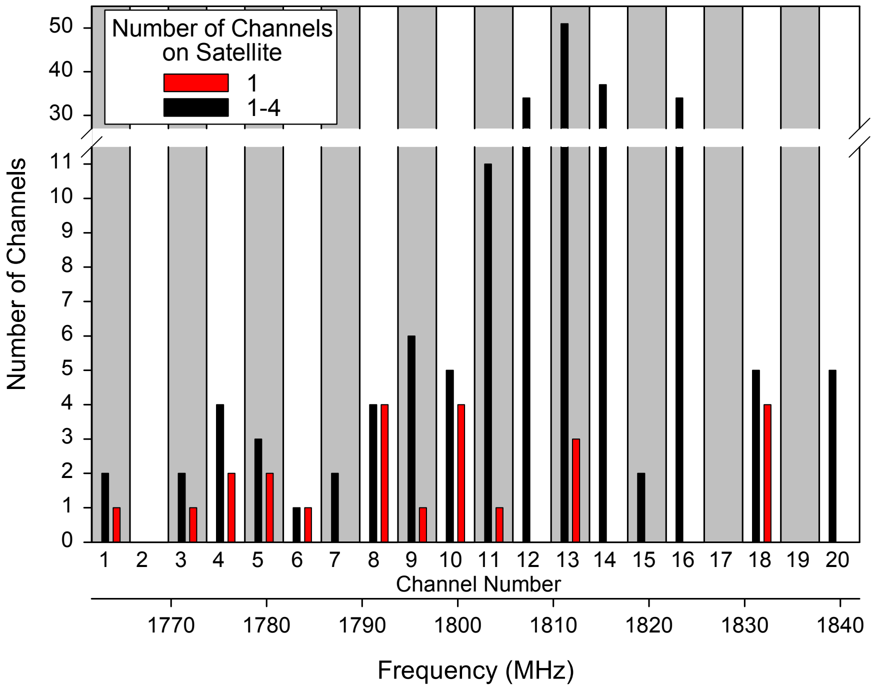

Figure 1. Histogram of Satellite utilization in 1761-1842 MHz.

1.1 Utilization of Channels 1-3

A limited number of systems use channels that overlap into the 1755-1770 MHz band. Channels 1 and 2 complete overlap the potential band for 3G deployments and Channel 3 overlaps 0.261 KHz of the band. Systems that operate in this band are L-92, USAPEX, IUS, P80-1 and the Space Shuttle. Shown in Table 1 are details associated with each satellite system.

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[1] Available to registered TIES users at http://www.itu.int/sns/.

[2] Satellites that can operate only on a single channel are indicated by the red bars. Black bars indicate total number of satellite channels at that frequency. For example a satellite that can operate in channels 1 and 3 would contribute once to the black bar for each channel 1 and 3.

Table 1: Systems operating in Channels 1-3

System Name	Orbit Information	Channels specified	Date of Bringing into use	Earth terminal information
L-92	NGSO Apogee – 1300 km Perigee – 650 km	Channel 1 1761.721 – 1765.721 MHz Channel 5 1777.736 – 1781.736 MHz	January 1992	-
USAPEX	NGSO Apogee – 1300 km Perigee – 650 km	Channel 1 1761.721 – 1765.721 MHz	August 1994	See Note[3]
P80-1	NGSO Apogee – 1300 km Perigee – 650 km	Channel 3 1769.729-1773.729 MHz	May 1985	See Note[4]
IUS[5]	NGSO	Channel 3 1770.729 – 1772.729 MHz Channel 4 1774.732 – 1776.732 MHz Channel 7 1786.740 – 1788.740 MHz Channel 15 1818.775 – 1820.775 MHz	February 1985	See Note[6]
Space Shuttle	NGSO Apogee – 1300 km Perigee – 650 km	Detached Payload[7] 1760-1840 MHz Channel 4 1773.732-1776.732 MHz Channel 18 1829.787-1833.787 MHz	December 1983	-

[3] Locations are Andersen, Guam; Vandenburg, CA; Kaena Point, HI; and New Boston, NH. All earth stations have a transmit gain of 45 dBi or 47 dBi. Maximum power supplied to antenna is 10 kW.

[4] Locations are Andersen, Guam; Vandenburg, CA; Kaena Point, HI; and New Boston, NH. All earth stations have a transmit gain of 45 dBi. Maximum power supplied to antenna is 1 kW.

[5] Discussions with DoD/NTIA/Aerospace officials in October 2001 indicate this is the Boeing Inertial Upper Stage used to lift payloads into upper orbits, mission about 7 hours in length, http://www.losangeles.af.mil/SMC/PA/Fact_Sheets/ius_fs.pdf, see Annex I.

[6] Locations are Andersen, Guam; Vandenburg, CA; Kaena Point, HI; and New Boston, NH. All earth stations have a transmit gain of 47 dBi. Maximum power supplied to antenna is 3.2 W.

[7] Maximum power supplied to detached payload antenna is 0.17 W.

1.2 Utilization of Channels 4-5

Out-of-band emissions from SATOPS (Satellite Operations) earth terminals operating in channel 4 will have the highest impact on interference to 3G systems relative to channels 5 and higher. As shown in Figure 2 the out-of-band emissions decrease with frequency separation. The aspect of reduced interference is illustrated by the green, yellow and red boxes in the figure, note that each box is 5 MHz in width. The red box indicates the emissions into 3G base station receivers operating in 1765-1770 MHz when the SATOPS earth terminal is operating in channel 4. The yellow box indicates the emissions levels in 1765-1770 MHz for SATOPS terminals operating in channel 5 and the green box indicates the levels in 1765-1770 MHz for SATOPS terminals operating in channel 6. Aspects should be noted, the

- The emissions levels are computer generates, there may be some variations with actual equipment and some level of testing/measurement should be under taken.
- Baseband filtering as a interference mitigation technique seems to give significant reduction for channel 5 and higher SATOPS earth terminals.
- Emssions from operations in channels 7 and higher will be similar to that found in channel 6

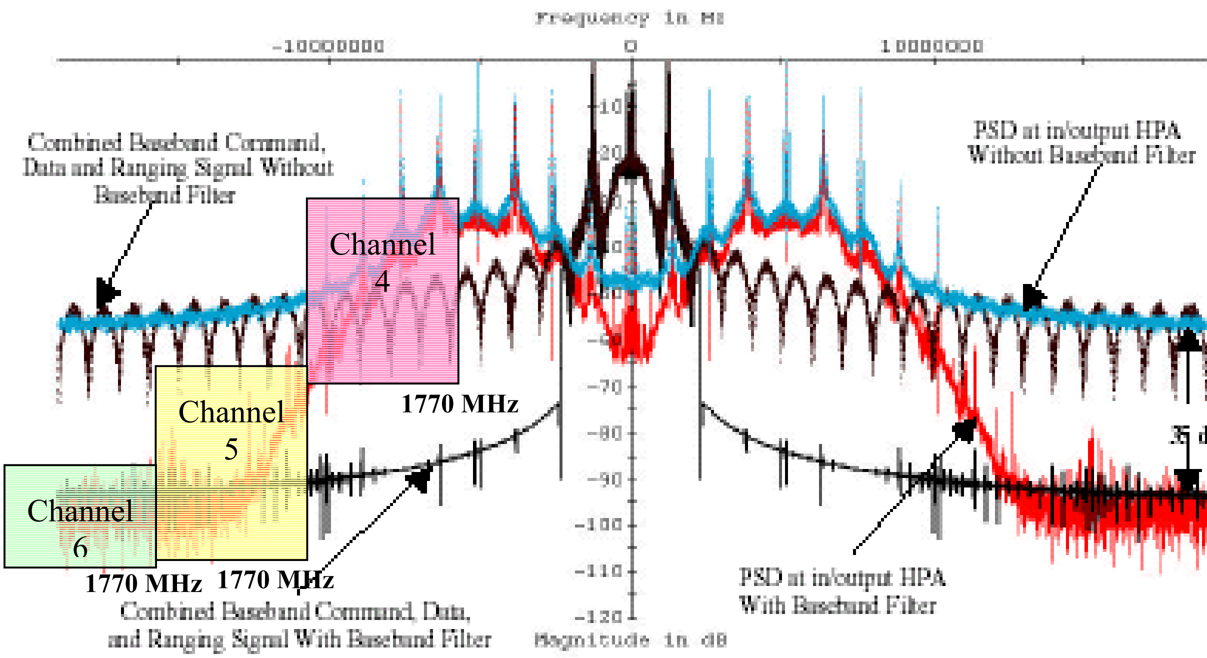

Figure 2: Computer Generated Emissions of SATOPS Uplink[8].

A limited number of systems use channels 4 and 5. Systems that operate in this band are ALEXIS, IUS, L-92, CRRES, P78-2 and the Space Shuttle. Shown in Table 1 are details associated with each satellite system.

[8] DoD Interim report, Figure C-2 at page C-4.

Table 2: Systems operating in Channels 4 and 5

System Name	Orbit Information	Channels specified	Date of Bringing into use	Earth terminal information
ALEXIS	NGSO Apogee – 835 km Perigee – 740 km	Channel 4 1773.995-1774.005 MHz	April 1993	See Note[9]
IUS[5]	NGSO	Channel 3 1770.729 – 1772.729 MHz Channel 4 1774.732 – 1776.732 MHz Channel 7 1786.740 – 1788.740 MHz Channel 15 1818.775 – 1820.775 MHz	February 1985	See Note[6]
Space Shuttle	NGSO Apogee – 1300 km Perigee – 650 km	Detached Payload[7] 1760-1840 MHz Channel 4 1773.732-1776.732 MHz Channel 18 1829.787-1833.787 MHz	December 1983	-
L-92	NGSO Apogee – 1300 km Perigee – 650 km	Channel 1 1761.721 – 1765.721 MHz Channel 5 1777.736 – 1781.736 MHz	January 1992	-
CRRES	NGSO Apogee – 35800 km Perigee – 350 km	Channel 5 1777.736-1781.736 MHz	July 1990	See Note[10]
P78-2	NGSO Apogee – 42781 km Perigee – 27851 km	Channel 5 1777.736-1781.736 MHz	July 1979	See Note[11]

2 Compatibility between 3G terrestrial systems and SATOPS operations

Assessment of the compatibility between 3G terrestrial systems and SATOPS operations can be divided into two aspects, 1) interference into SATOPS satellite receivers from 3G terrestrial mobile terminals and 2) interference into 3G terrestrial base station receivers from SATOPS earth terminals.

[9] Located at Los Alomos, NM. Earth station has a transmit gain of 12 dBi. Maximum power supplied to antenna is 38 W. Transmit bandwidth is specified as 10 KHz.

[10] Locations are Andersen, Guam; Vandenburg, CA; Kaena Point, HI; and New Boston, NH. All earth stations have a transmit gain of 45 dBi or 46 dBi. Maximum power supplied to antenna is 10 kW.

[11] Locations are Andersen, Guam; Vandenburg, CA; Kaena Point, HI; and New Boston, NH. All earth stations have a transmit gain of 45 dBi or 47 dBi. Maximum power supplied to antenna is 10 kW.

The first aspect of interference into the SATOPS from 3G mobile terminals has been studied by both the Industry[12] and the NTIA[13], with similar results with respect to ability to co-exist but with significant different results with respect to the level of interference. Industry computed levels of interference much lower than that found by the DoD, but the key point is that both analyses indicated that under full build-out condition that the communications links to the satellite will have a positive margin[14].

The remainder of this report will focus on the compatibility aspects on the second point which address interference into 3G terrestrial base stations receivers from SATOPS earth terminals.

2.1 Interference from Channel 1-3 operations

Nature of TT&C operations is that a small number of satellite operations will limit the potential for interference

- ITU Space Network System (SNS) data indicates that relatively few systems would be on-channel with 3G terrestrial systems, those systems should use alternative channels if possible.
- Only 2 Systems are shown as having no alternative to using channels in 1762-1770 MHz
    - USAPEX (1761.721 – 1765.721 MHz)
    - P80-1 (Partial overlap of 261 kHz at 1769.729 – 1770 MHz)
        - Currently in 16 years in operation and should be nearing end of life, and is likely to no longer be in use by the time 3G systems begin operation.

Interference to 3G Base Station Operations is primarily limited to a single system USAPEX. This system is currently in operation 8 years; estimates on end of life will indicate the need for further investigation if any mitigation is required. In the event that the end of life of this system conflicts with 3G deployments, application of the mitigation techniques indicated in Section 2.3 (page 7) should be considered.

2.2 Interference from Channel 4-5 operations

Three systems are found to use channel 4 (ALEXIS, IUS and the Space Shuttle), since both IUS and the Space Shuttle are short-term use systems and these systems have the capacity to use alternate channels, the only system at issue in channel 4 is ALEXIS. ALEXIS has operational characteristics that enable it to be more compatible with 3G base station operations. Those characteristics are:

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[12] Industry Association Report, 22 February 2001.

[13] DoD Final Report, 9 February 2001.

[14] Point of agreement also cited in the Report to the Ranking Minority Member, Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate, Appendix 1, p.29, "*While they disagree on the specifics of the interference estimates, both DOD and industry agree that low-power mobile stations are much less likely to cause significant interference with DOD satellite operations.*"

- The transmission bandwidth is 10 kHz as opposed to the typical 4 MHz bandwidth. This much narrower bandwidth would result in significantly faster roll-off of the out-of-band emissions and hence a lower chance of interference.
- The transmit power, 38 W, supplied to a lower gain antenna, 12 dBi, results in a significantly lower radiated power, EIRP of 27.8 dBW, than that found with most SATOPS terminals which have EIRP of up to 87 dBW.

Three systems are found to use channel 5 (L-92, P78-2 and CRRES).

- P78-2 has been in operation for 22 years, unlikely to be in operation in the time frame significant deployment of 3G systems.
- L-92 has been in operation for 10 years and CRRES have been in operation for 12 years, further investigation should occur with respect to the end-of-life for these systems.
    - In the event that the end of life of these system conflicts with 3G deployments, application of the mitigation techniques indicated in Section 2.3 (page 7) should be considered.

2.3 Interference Mitigation Measures

Shown in Table 3 are various mitigation methods that can be used to reduce interference potential between a SATOPS earth terminal and a 3G terrestrial base station. The majority of interference can be significantly reduced with the application of baseband filters for SATOPS terminals that operate in channels 6 and higher[15]. It is estimated that these two factors will decrease the interference power into 3G terrestrial base stations by nearly 90 dB. This effectively reduces the power seen in the base station receiver to levels similar to that of a single 3G mobile terminal[16].

Table 3: Mitigation methods to reduce interference potential.

Operation in channels 6 and higher	~ **55 dB**
Base band filtering	upto **35 dB**
Operation at higher elevation angles	**~ 10-20 dB**
Operation at reduced power levels	~ **10-20 dB**
Base station antenna pattern nulling	~ **5-10 dB**
Lower 3G base station heights	~ **2-5 dB**
Polarization	~ **3 dB**
Signal blockage / Antenna redesign	?? **dB**
Time or Geographic sharing Off loading of satellite operations to remote locations Cooperative Scheduling Zones of no 3G operations	

[15] DoD Interim Report at Appendix C, p. C-3 to C-4; Industry Association Report, p. 5 and Attachment I p.C-9.

[16] The peak radiated power of a 47 dBi antenna when supplied with 10 kW is 87 dBW, a 90 dB reduction would result in 0.5 W of power radiated in the 3G base station receive band. A 3G mobile terminal has a peak power level of ¼ W to 1 W.

As shown above currently questions remain about four systems, two operating in channels 1-3 (USAPEX and P80-1) and two operating in channels 5 (P78-2 and L-92) where further mitigation would be required for compatibility with 3G base stations. Below are some more detailed views on the various mitigation techniques.

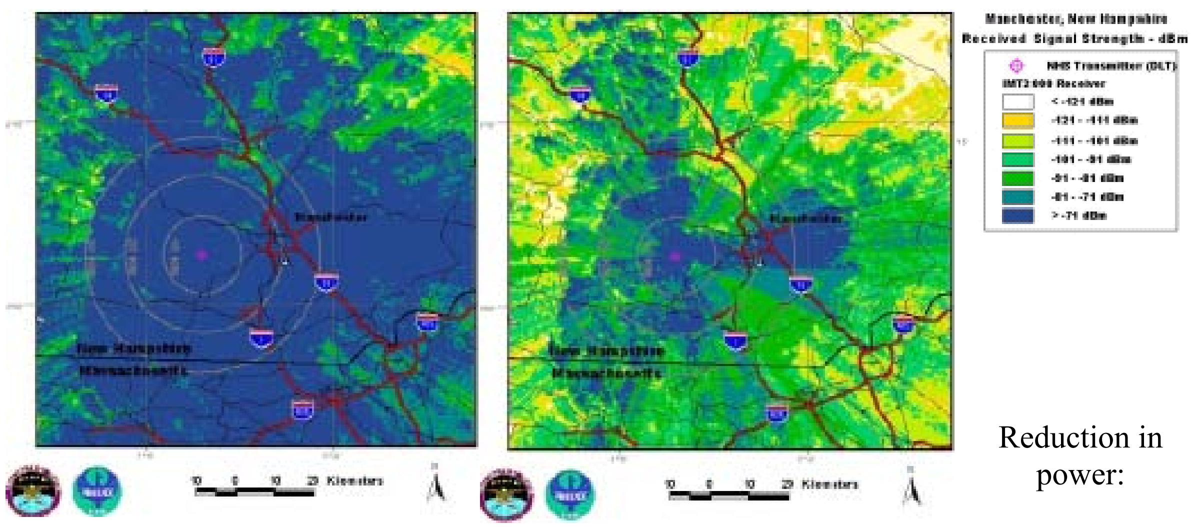
2.3.1 Operation at high elevation angles

All of the 4 systems listed above where further mitigation may be required are of the NGSO type, this means that during communications the elevation angles change as a function of time. This variation in elevation angle allows the possibility of scheduled communication such that use of these links occur at the highest elevation angles possible

As an example consider the earth terminals associated with P80-1 and USAPEX, the antenna patterns indicate that 15 dB reduction in interference levels would result in operations occurring at 10° as opposed to 3°.[17]

2.3.2 Operation at reduced power levels during normal operations

Link closure can typically be achieved at powers in the 100 to 500 Watt range for satellites on orbit and under nominal operating conditions[18]. Note that during critical periods of time where loss of satellite is a potential, all measures to communicate should be available (i.e. operation at any elevation angle and maximum power).



		Reduction in power:
3° Transmit Elevation	10° Transmit Elevation	15 dB
2500 W Transmit Power	100 W Transmit Power	14 dB

Figure 3: Reduction in interference levels by application of higher elevation angles and lower transmit powers.[19]

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[17] DoD Final Report at Appendix B, Table B-8, p. B-18 and B-33; Industry Association Report, Attachment I, p. C-8.

[18] DoD Final Report at Appendix B, p. B-33 to B-34; Industry Association Report, at p. 5 and Attachment I p. C-8.

[19] DoD Final Report at Attachment 1, for NHS-B (46 dBi) antenna located in Manchester, NH

2.3.3 Off-load operations to geographically remote terminals

Where satisfactory visibility can be achieved, it may be possible that some of the operations currently performed by terminals in populated areas could be off-loaded to more remote terminals.[20]

2.3.4 Signal blockage / Antenna redesign

Intentional signal blockage can be achieved via a cylinder surrounding the SATOPS antennas to reduce spillover, modification of the feed, or modification of the illumination taper to reduce sidelobes at the expense of gain.[21]

2.3.5 3G cellular systems

Multiple measures have been suggested for evaluation in the DoD report[22], some are also suggested in the Industry reports:

- Keep out zones about DoD earth terminals / Reduced coverage area of 3G systems[23]. If keep out-zones are considered, they should be as small as possible. In the determination of these zone models such as used in the DoD report (TIREM) or the ITM model should be used. See section 3, page 10 of this report for more details.
- Base station antenna pattern nulling to avoid main beam interactions with DoD earth terminals
- Polarization

2.3.6 Cooperative scheduling

A time scheduling technique in which 3G systems would be notified of use of a SATOPS earth terminal and move traffic to a frequency where interference is less likely.[24]

2.3.7 Evaluation of 3G systems use of lower base station antenna heights

Analysis focused on base stations use of 40 m antenna height, propagation models typically predict greater losses when base stations are at lower heights. In addition to propagation loss due to the irregular terrain other losses are increased when base stations operate a lower heights. These losses are due to obstruction, such as trees and buildings, that can significantly increase the actual loss between a SATOPS earth terminal and a 3G base station receiver.

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[20] DoD Final Report at Appendix B, p. B-33; Industry Association Report, Attachment I, p. C-8.

[21] DoD Final Report at Appendix B, p. B-33; Industry Association Report, Attachment I, p. C-9.

[22] DoD Final Report at Appendix B, p. B-34.

[23] Industry Association Report, Attachment I, p. C-9.

[24] DoD Final Report at Appendix B, p. B-34 to B-35; Industry Association Report, p. 5.

3 Propagation Model Review – ITM (Longly-Rice) / TIREM / Free Space

ITM – Irregular Terrain Model – Developed by the Institute for Telecommunication Sciences at the U.S. Department of Commerce (http://elbert.its.bldrdoc.gov/itm.html)

TIREM – Terrain Integrated Rough Earth Model – Maintained by DoD's Joint Spectrum Center (JSC) and distributed by NTIA to Federal Agencies.

3.1 Comparison of ITM model to Free space Loss

In the estimation of the propagation loss between two point locations for the purposes of estimating interference or exclusion zones the most accurate modeling should be applied in order not to overly constrain either the transmitting or receiving systems. As an example of this factor consider the propagation loss between the New Hampshire satellite tracking site (42 56 52 N, 71 37 37 W) and Boston, MA (42 20 10 N, 71 01 04 W). Shown in Figure 4 is the elevation profile between the SATOPS earth terminal, located at 0, and Boston, MA[25].

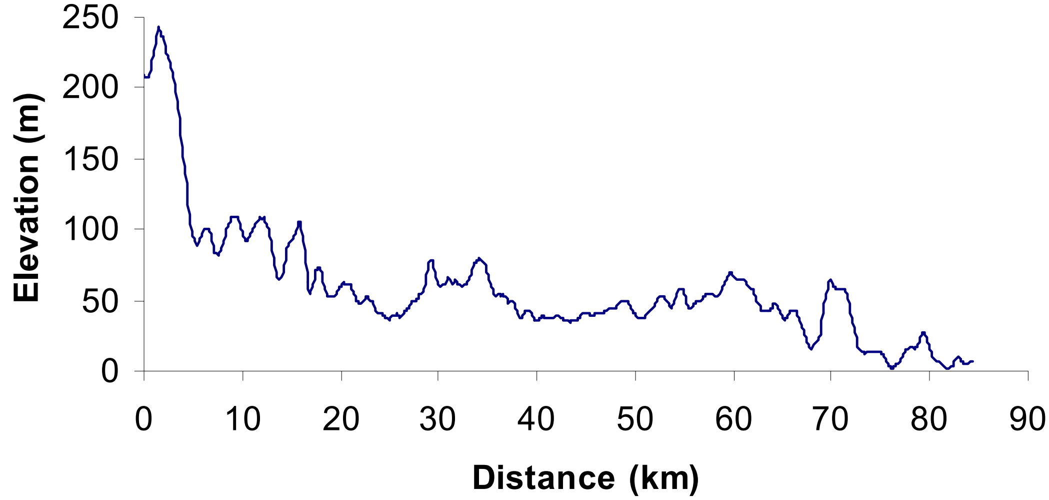

Figure 4: Elevation profile between New Hampshire tracking site and Boston, MA.

Table 4: Parameters used to evaluate propagation loss between NH tracking site and Boston, MA.

Transmitter height	15 m
Receiver height	40 m
Frequency	1770 MHz
Polarity	Horizontal

Dielectric Constant of Ground	Temperate - 15
Surface Refractivity	Average Ground - 301
Conductivity of Ground	Average Ground – 0.005 S/m
Radio Climate	Temperate

[25] Elevation data is obtained from NOAA Globe database, http://www.ngdc.noaa.gov/seg/topo/globe.shtml.

From the elevation profile found in Figure 4 and the parameters shown in Table 4 the propagation loss is computed and shown in Table 5. The separation distance is 84.3 km and at 1770 MHz the free space loss is 135.9 dB

Table 5: Confidence the Attenuation will not be exceeded for at least the specified percentage of time

Percent of time	Confidence Level			
	10	*50*	*90*	*99*
1	168.7	180.4	192.1	199.7
10	182.6	191.3	200.0	206.4
50	194.9	202.2	209.6	215.6
99	206.7	216.0	225.3	232.0

As illustrated above the expected losses over free space propagation is at least 33 dB and with less likely hood (or smaller percentages of time) the propagation loss can be much higher. Specifying of coordination zones or keep out zone would unduly restrict operations if less accurate models, such as free space, are utilized.

3.2 Building / Vegetation Loss

One aspect that is not taken directly into account in many of the model is the losses that would be experienced by factors other than terrain. These losses primarily are due to either a man made structure between the transmitter and receiver or some vegetation.

Vegetation loss has been quantified by many empirical studies and is found to vary as a function of frequency. ITU-R recommendation P.833-3[26] predicts that for propagation through woodland, which has a specific attenuation of around 0.4 dB/m, the loss through 100 m of forest would result in an additional 27 dB of loss[27].

Propagation through buildings has also been the subject of many measurement campaigns and studies. The ITU has specified this loss in particular to evaluate the effects on terrestrial systems and are reflected in ITU-R recommendations M.1225[28] and P.1238[29]. Shown in Table 6 are some of the loss factors that are encountered in propagation through a building, as indicated significant amounts of loss are predicted. ITU-R recommendation P.1238 also includes other factors such as office equipment and various office furnishings that add additional losses over those structural losses indicated previously.

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[26] ITU-R Recommendation P.833-3, "Attenuation in vegetation," 2001.

[27] Attenuation is computed by Am*(1-exp(-d*gamma/Am)), where Am is the maximum attenuation for one terminal within a specific type and depth of vegetation, d is the distance into the vegetation, gamma is the specific attenuation. For this example Am = $0.18*f^{0.752}$ where f is frequency in MHz and is based on measurements (see ITU-R P.833).

[28] ITU-R Recommendation M.1225, "Guidelines for evaluation of radio transmission technologies for IMT-2000," 1997, see Appendix 1 to Annex 2.

[29] ITU-R Recommendation P.1238-2, "Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 900 MHz to 100 GHz," 2001.

Table 6: Loss categories for various building structure elements[28].

Loss category	Description	Loss Factor (dB)
Lf	Typical floor structures (i.e. offices) – Hollow pot tiles – Reinforced concrete – Thickness type < 30 cm	18.3
*Lw*1	Light internal walls – Plasterboard – Walls with large numbers of holes (e.g. windows)	3.4
*Lw*2	Internal walls – Concrete, brick – Minimum number of holes	6.9

3.3 Comparison of The Application of ITM and TIREM to TV propagation[30]

Summary:

- Both models under predict measured loss
  - ITM – 7-17 dB stronger signals than measurements
  - TIREM – 5-10 dB stronger signals than measurements
- Land use variations (local buildings, foliage, etc.) seem to account for the large errors on unobstructed paths.

COVERAGE PREDICTION

For many years, the method most broadcast engineers used to measure coverage was the FCC F (50,50) graphs in Section 73.699, Figures 9 and 10, of the FCC rules. These propagation curves are based on a combination of actual signal strength measurements and calculations of field strength. The FCC's allocation tables for analog TV were based on these curves.

When it became necessary to fit DTV channels into the same spectrum shared with analog TV, the FCC decided a more precise method of calculating coverage was needed and decided to use the Irregular Terrain Model (ITM) developed by the Institute for Telecommunication Sciences at the U.S. Department of Commerce. ITM is more commonly called the Longley-Rice model, after the scientists who developed it.

The FCC curves provide the distance to a field strength contour (or field strength at a certain distance) for a given power level at a particular height above average terrain (HAAT). HAAT is calculated by averaging the height of the center of radiation of the antenna over terrain 3.2 to 16.1 km from the antenna along the radial studied.

[30] http://www.tvtechnology.com/features/On-RF/f-dl-dtv-coverage.shtml#

Longley-Rice, on the other hand, considers all terrain between the transmitting antenna and a specific receive point, so a coverage map will look like a checkerboard of cells (2 square km or less under FCC OET Bulletin 69) instead of a set of concentric contours. Because it more accurately accounts for terrain, it allowed the FCC to re-use channels in areas where terrain blocked interference.

PROPAGATION MODELS

To overcome some perceived problems with the Longley-Rice model, some consultants use another model, called "TIREM," that chooses among different propagation models based on the characteristics of the path to a particular point, avoiding the Longley-Rice "Error Code 3" problem.

William Meintel, in his paper "Television Service Predictions – Actual Measurements Versus Computer Modeling," compared the FCC curves, Longley-Rice (as implemented in FCC OET Bulletin 69) and TIREM with 2,937 measurements from stations on Channels 2 through 47 taken between 1998 and 2000 using the standard techniques described by Gary Sgrignoli for DTV field measurements. Data was taken from the recent MSTV-sponsored 8-VSB/COFDM study and from studies conducted in individual markets. These studies included paths over flat land, rolling hills and rugged terrain. Data was evaluated for "believability" before a measurement was used.

For the computer modeling, William Meintel used 3-second terrain data and 0.1 km terrain intervals. The antenna pattern, including the elevation pattern where available, was used in the calculations.

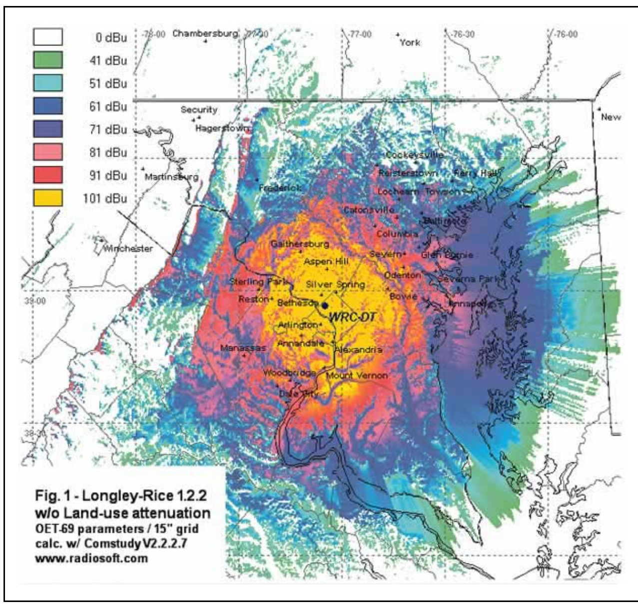

Fig. 1 - Longley-Rice 1.2.2
w/o Land-use attenuation
OET-69 parameters / 15" grid
calc. w/ Comstudy V2.2.2.7
www.radiosoft.com

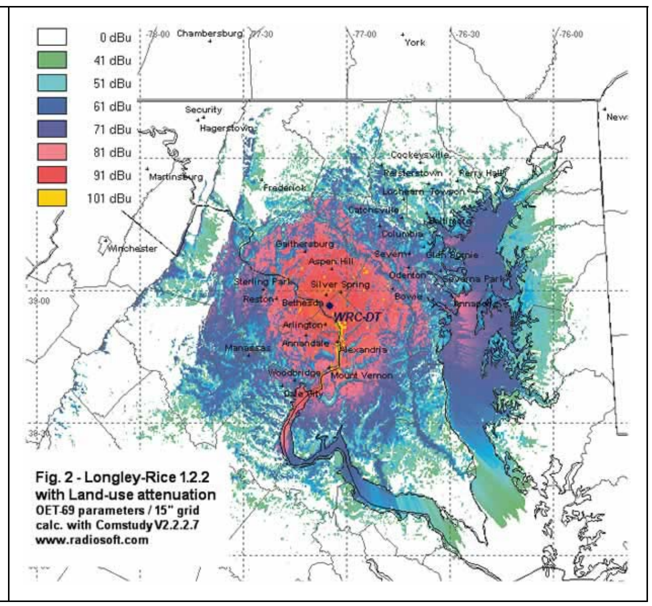

Fig. 2 - Longley-Rice 1.2.2
with Land-use attenuation
OET-69 parameters / 15" grid
calc. with Comstudy V2.2.2.7
www.radiosoft.com

Overall, Longley-Rice predicted signal levels 7 to 17 dB stronger than the levels measured in the field tests. TIREM was slightly better, predicting signal levels 5 to 10 dB stronger than measured. TIREM did better on paths with fewer obstructions, whereas Longley-Rice performed better with more obstructions.

William Meintel concluded that the models were okay for "apples to apples" comparisons, but that they tend to over-predict actual signal strength. Longley-Rice and TIREM did better over longer paths.

INDIVIDUAL POINTS

Neither Longley-Rice nor TIREM should be considered valid when looking at individual points. Predictions for individual points showed a large standard deviation when compared with the field measurements, even for unobstructed paths. During the question-and-answer period, it was suggested that variations in land use (local buildings, foliage, etc.) could have accounted for the large errors on unobstructed paths.

Clearly, models that are more complex are needed if we want more accurate coverage prediction. Some propagation software for land-mobile and cellular requires land-use data. In fact, point-to-point coverage studies for determining coverage under the U.S. Satellite Home Viewers Improvement Act require land-use data. This information is readily available. RadioSoft's ComStudy software allows adding land-use attenuation to its Longley-Rice studies.

Figures 1 and 2 compare the field strengths predicted for WRC-DT at 813 kW ERP by Longley-Rice both with and without land-use attenuation. As you can see, land use does affect coverage. Both figures were calculated using OET-69 parameters for Longley-Rice coverage, with land use attenuation added in **Figure 2**. Cell size was 15 seconds, approximately 500 meters square. The OET-69 default elevation pattern was used.

4 Description of IUS systems[31]

FACT SHEET

UNITED STATES AIR FORCE

The Inertial Upper Stage

The Inertial Upper Stage has successfully placed more than 21 nationally critical satellites and interplanetary payloads into space. The Air Force Space and Missile Systems Center is the executive agent for all Defense Department activities pertaining to the IUS and provides the upper stage booster to NASA for space shuttle use. The Inertial Upper Stage rocket motor provides the U.S. government with the ability to place satellites up to 5,300 pounds into geosynchronous orbit and 8,000 pounds out of Earth's gravitational field using the Air Force Titan IVB rocket or NASA Space Shuttle.

A Boeing Inertial Upper Stage two-stage rocket motor.
Photo: The Boeing Company

The prime contractor for the Inertial Upper Stage is Boeing Space & Communications in Seal Beach, California. The Boeing IUS production facility is located in Kent, Washington. Boeing began development of the two-stage payload delivery vehicle in 1976 and saw the first IUS fly on a Titan launch vehicle in 1982. The fundamental elements of the IUS include: two high performance solid-rocket motors; an interstage; an equipment support section that includes the redundant avionics for guidance, navigation, and communications; a reaction control system; and an electrical power system. The IUS is almost 17 feet long, up to 9½ feet in diameter and weighs approximately 32,500 pounds.

The Air Force has used the IUS to boost missile warning and communications satellites into operational orbits. The Defense Support Program satellites have used the IUS on both the space shuttle (STS-44) and expendable Titan launch vehicles, and a Defense Satellite Communications

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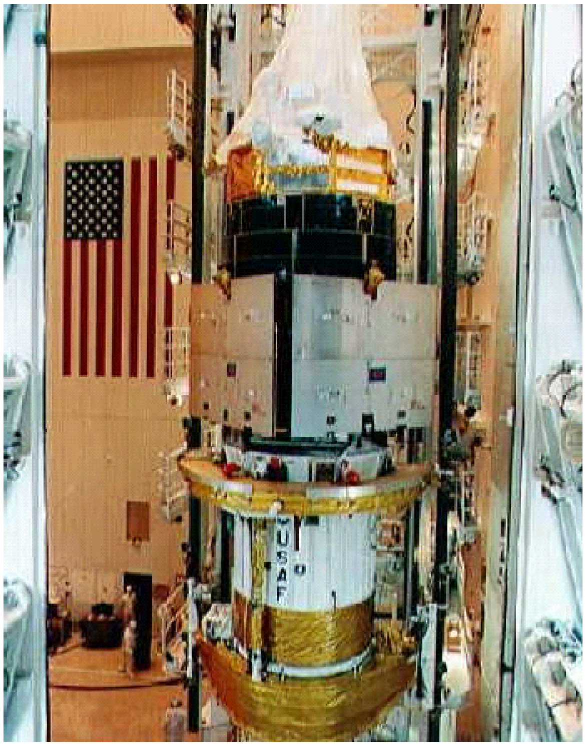
[31] http://www.losangeles.af.mil/SMC/PA/Fact_Sheets/ius_fs.pdf



The Inertial Upper Stage is mated with the Defense Support Program satellite for launch from the Space Shuttle Atlantis. NASA photo

System spacecraft used an IUS on Space Shuttle Flight 51 to reach operational orbit. In addition, the IUS was selected by NASA as an upper stage for its Tracking and Data Relay Satellite constellation and the prominent Magellan, Galileo, Ulysses, and Chandra science missions. Launched in May 1989, the Magellan spacecraft traveled to Venus and successfully mapped more than 85% of the planet's surface. The Galileo spacecraft was launched in October 1989, and is continuing its mission to explore and send back crucial data on the giant of the solar system – the planet Jupiter. In October 1990, the IUS sent the solar explorer Ulysses, a European Space Agency spacecraft, toward a polar orbit of the sun. Finally, in 1999, an IUS put the orbiting space observatory Chandra into orbit.

A typical Titan IVB launch works this way: about nine minutes into flight, the Titan second stage booster separates from the IUS. The IUS takes over responsibility for the remainder of the powered portion of the flight. For the next 6 hours and 54 minutes, the IUS autonomously performs all functions to place the spacecraft into its proper orbit, approximately 22,000 miles above the Earth. The first IUS rocket burn comes a little over one hour into the IUS booster flight. The IUS second solid rocket motor ignites around 6 1/2 hours into the flight, followed by an additional coast phase and payload separation.

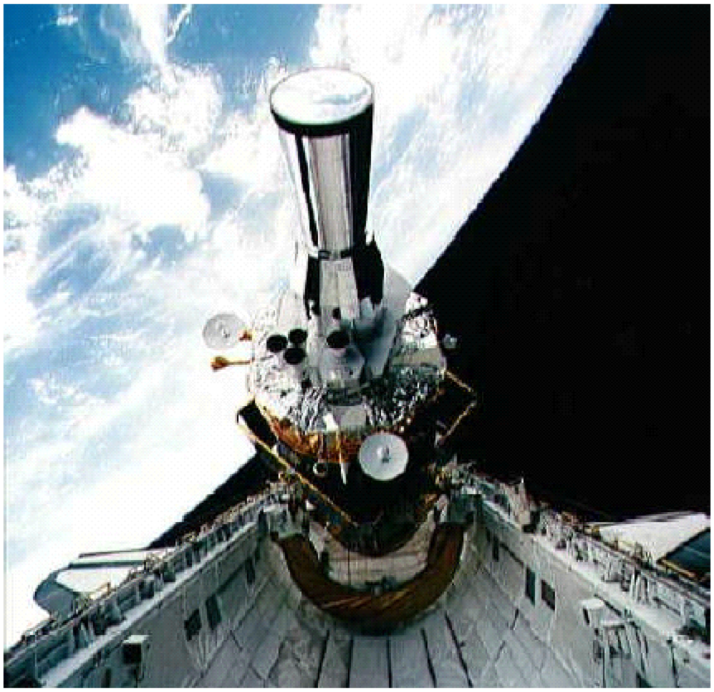
In addition to firing its two stages, the IUS also performs "rotisserie-like" roll maneuvers to protect the satellite from damage due to extreme heat or cold prior to spacecraft separation.

For a typical space shuttle flight, after reaching low-Earth orbit, the shuttle opens its payload doors and the IUS is rotated into deployment position using the IUS compatible Aerospace Support Equipment. After satellite and IUS checkout, the shuttle astronauts eject the IUS and its cargo from the orbiter. The IUS onboard computers then direct a series of preparatory maneuvers and fire the first-stage motor for approximately 140 seconds to propel the IUS and spacecraft toward the desired geosynchronous position.

After a coast period of several hours, the second stage motor burns for approximately 100 seconds and injects the IUS into a final circularized orbit. The IUS then separates from the satellite and moves to a position where it neither collides with nor contaminates the satellite.

The Air Force has three IUS vehicles in remaining inventory. Currently, two of these vehicles are manifested to fly nationally critical Defense Support Program satellites in summer 2001 and spring 2003.

Data on the Inertial Upper Stage



DSP-16 and the IUS booster are checked out in the cargo bay of Space Shuttle Atlantis prior to release. NASA photo

Primary mission:
Boost payloads to geosynchronous orbit

Prime Contractor:
The Boeing Company

Length: 16.4 feet

Diameter: Flares from 7.5 to 9.5 feet

Thrust:
SRM-1: 41,700 pounds
SRM-2: 17,200 pounds

Propellants: Solid - Cast Hydroxyl-Terminated Polybutadiene, Aluminum, andAmmonium Perchlorate

Total Boosters built: 25